December 2014

Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2013: Proposed Revision to Well Counts Data

Update Under Consideration for Public Review Draft

Overview of Well Counts in the GHG Inventory

A significant number of emission sources in the natural gas and petroleum systems source categories of the Inventory rely on well counts. The well count populations historically used in the Inventory are presented in Table 1. Note that the associated gas well counts currently in the natural gas systems portion of the Inventory are a subset of oil wells, which are the primary well population used in the petroleum systems portion of the Inventory.

Table 1. Well Populations and Use in the 2014 Inventory for Natural Gas and Petroleum Systems

Well Population	Well Population Description	Inventory Emission Sources Estimated Using Well Population Data
Natural Gas Systems		
Associated Gas Wells	Oil wells that also produce gas	• Fugitive ○ Field Separation Equipment – Meters/Piping

Non-Associated Gas Wells	Natural gas wells	• Fugitive
		  ○ Non-Associated Gas Wells
		  ○ Field Separation Equipment – Heaters, Separators, Dehydrators, Meters/Piping
		  ○ Gathering Compressor – Small and Large Reciprocating Compressors, Large Reciprocating Stations, Pipeline Leaks
		• Vented and Combusted
		  ○ Gas Well Completions without Hydraulic Fracturing
		  ○ Well Drilling
		  ○ Normal Operations – Pneumatic Device Vents, Chemical Injection Pumps, Kimray Pumps, Dehydrator Vents
		  ○ Compressor Exhaust for Gas Engines
		  ○ Well Workovers – Gas Wells without Hydraulic Fracturing, Gas Wells with Liquids Unloading
		  ○ Blowdowns – Vessel Blowdowns, Pipeline Blowdowns, Compressor Blowdowns, Compressor Starts
		  ○ Upsets – Pressure Relief Valves, Mishaps

Non-Associated Gas Wells (cont.)	Natural gas wells (cont.)	

Gas Wells with Hydraulic Fracturing	Natural gas wells that were completed using hydraulic fracturing	• Fugitive
		  ○ Gas Wells with Hydraulic Fracturing
		  ○ Field Separation Equipment – Heaters, Separators, Dehydrators, Meter/Piping
		  ○ Gathering Compressor – Small and Large Reciprocating Compressors, Large Reciprocating Stations, Pipeline Leaks
		• Vented and Combusted
		  ○ Gas Well Completions without Hydraulic Fracturing
		  ○ Gas Well Completions with Hydraulic Fracturing
		  ○ Well Drilling
		  ○ Normal Operations – Pneumatic Device Vents, Chemical Injection Pumps, Kimray Pumps, Dehydrator Vents
		  ○ Well Workovers – Gas Wells without Hydraulic Fracturing, Gas Wells with Hydraulic Fracturing
		  ○ Blowdowns – Vessel Blowdowns, Pipeline Blowdowns, Compressor Blowdowns, Compressor Starts
		  ○ Upsets – Pressure Relief Valves, Mishaps

Table 1. Well Populations and Use in the 2014 Inventory for Natural Gas and Petroleum Systems

Well Population	Well Population Description	Inventory Emission Sources Estimated Using Well Population Data
Petroleum Systems		
Oil Wells	Oil wells	• Fugitive ○ Oil Wellheads (Heavy Crude) ○ Oil Wellheads (Light Crude) ○ Separators (Heavy Crude) ○ Separators (Light Crude) ○ Heater/Treaters (Light Crude) ○ Compressors ○ Headers (Heavy Crude) ○ Headers (Light Crude) ○ Battery Pumps • Vented ○ Pneumatic Devices, High Bleed ○ Pneumatic Devices, Low Bleed ○ Vessel Blowdowns ○ Compressor Blowdowns ○ Compressor Starts ○ Well Workovers • Combusted ○ Gas Engines
Stripper Wells	Oil wells that produce less than 10 bbl/day	• Fugitive ○ Oil Wellheads (Heavy Crude) ○ Oil Wellheads (Light Crude) • Vented ○ Oil Tanks ○ Stripper Wells • Combusted ○ Flares

Approach for 2012 and Previous Inventories

Data sources for well counts in the natural gas and petroleum systems portions of the Inventory have changed over time. For 2012 and previous Inventories, the well counts data came from the following publically available sources:

- Natural gas systems:
  - Associated gas wells:
    - 1990 to 2004 data: API *Basic Petroleum Book* Table 12 – Section III – Producing Oil Wells in the United States by State (2005)
    - 2005 to 2010 data: *World Oil Magazine* Outlook 2011: Producing Oil Wells
  - Non-associated gas wells:
    - 1990 to 2003 data: U.S. DOE/EIA Annual Number of Producing Gas Wells[1]
    - 2004 to 2010 data: *World Oil Magazine* Outlook 2011: Producing Gas Wells
  - Gas wells with hydraulic fracturing:
    - CBM wells in KS: Kansas Geological Survey All Wells
    - CBM wells in OK: Oklahoma Geological Survey Coalbed Methane Completions

[1] "Number of Producing Gas Wells." Energy Information Administration, U.S. Department of Energy. Available online at http://www.eia.gov/dnav/ng/ng_prod_wells_s1_a.htm

  - CBM wells in MT: Montana Department of Natural Resources and Conservation, Board of Oil and Gas Live Data Access
  - CBM wells in CO: Colorado State Oil and Gas Conservation Commission Coalbed Methane Wells
  - CBM wells in WY: Wyoming Oil and Gas Conservation Commission Coalbed Production
  - CBM wells in UT: Utah Department of Natural Resources, Division of Oil, Gas and Mining Well Information Search
  - Barnett shale wells in TX: Texas Railroad Commission Newark, East (Barnett Shale) Well Count
- Petroleum systems:
  - Oil wells: EIA Annual Energy Review Table 5.2. Crude Oil Production and Oil Well Productivity[2]
  - Stripper wells:
    - 1990 to 1992 data: API Basic Petroleum Data Book Section III Table 14 (2002)
    - 1993 to 2010 data: Interstate Oil and Gas Compact Commission Marginal Wells: Fuel for Economic Growth, Table 7.1 (2008)

Approach for 2013 and 2014 Inventories

As part of EPA's updates for the natural gas systems portion of the 2013 and 2014 Inventories, EPA revised the well counts for each category using DrillingInfo's U.S. well data. Updating the well count data source allowed for a more transparent, consistent, and reproducible methodology for obtaining well counts as follows:

- Associated gas wells are defined as those wells in the DrillingInfo dataset that:
  - EPA classified as primarily producing "oil" or "oil and gas" based on the production type description and that had non-zero natural gas; ***and***
  - Had non-zero hydrocarbon liquids production.
- Non-associated gas wells are defined as those wells in the DrillingInfo dataset that:
  - EPA classified as "gas" producing and had non-zero gas production; ***or***
  - EPA classified as "oil" or "oil and gas" producing and had zero liquids production, but non-zero natural gas production.
- Gas wells with hydraulic fracturing are defined as a subset of the non-associated gas wells that:
  - Were horizontally drilled; ***and/or***
  - Located in an unconventional formation (i.e., shale, tight sands, or coalbed), as identified using a crosswalk developed by EIA.

EPA did not make any changes to the well counts data sources in the petroleum systems portion of the 2013 or 2014 Inventories.

EPA has previously investigated differences between non-associated gas well counts from the previous activity data sources (EIA and *World Oil Magazine*) compared to the current methodology which relies on DrillingInfo data. In general, DrillingInfo counts are lower than those generated by the previous methodology. EIA counts of active gas wells exclude wells producing both crude oil and natural gas[3]—whereas the current DrillingInfo methodology results in some co-producing wells being included in the non-associated gas well counts. Therefore, based on available documentation, the underlying reasons for differences in the previous gas well counts compared to those generated by the current methodology is unclear. EPA has previously performed state-level count comparisons and taken steps to refine the DrillingInfo processing methodology to resolve significant discrepancies (e.g., DrillingInfo collects production data on a

[2] "Annual Energy Review." Energy Information Administration, U.S. Department of Energy. Available online at http://www.eia.gov/totalenergy/data/annual/index.cfm

[3] *Annual Energy Review 2011*. Energy Information Administration, U.S. Department of Energy. Available online at http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf

well pad level in certain states; therefore, EPA refined the processing methodology to account for single production records representing multiple active wells). Table 2 below shows well counts for key comparison years from both previous (2012 Inventory) and the most recent (2014 Inventory) methodology.

Revised Approaches Under Consideration

Table 2 below presents well count activity data for select years from the 2012 and 2014 Inventories, as well as example counts developed by three proposed approaches for the 2015 Inventory. Option 1 described below uses the current Inventory methodology to identify wells in natural gas systems (including associated gas wells), and expands the methodology to also develop petroleum systems counts (i.e., oil well counts). Option 2 described below greatly simplifies the current Inventory methodology in the interest of easier reproducibility; the ratio of gas to oil production ("gas-to-oil ratio" or GOR) based on DrillingInfo data is used to assign wells between the natural gas and petroleum systems source categories, and there is no sub-population of "associated gas" wells within natural gas systems. Option 3 described below expands on Option 2 to acknowledge the idea that oil wells with significant gas production should be treated differently than primarily gas-producing or oil-producing wells (as they are expected to have emissions somewhere between the two populations)—and therefore includes a population of "associated gas" wells, similar to the current Inventory and Option 1.

The approaches under consideration are:

1. For each year, classify all active production wells in the DrillingInfo database as "Non-associated Gas Wells," "Oil Wells," and "Associated Gas Wells" (a sub-population of oil wells)—starting with existing Inventory methodology for natural gas systems.
    a. Start with the OECA-processed version of the DrillingInfo database, which includes a PROD_TYPE_CLASS data field that EPA populates with the primary production type of each active oil and gas well (based on information reported by the operator and/or assigned by the state). This PROD_TYPE_CLASS field is populated with one of three values for each well: "GAS," "OIL," or "O&G."
    b. Assume that all wells that are classified as "GAS" and produced gas in a given year are "Non-associated Gas Wells" (and any amount of liquids produced is condensate). Assume that any wells classified as "OIL" or "O&G" that produced gas but zero liquids in a given year are also "Non-associated Gas Wells."
    c. Assume that all wells that are classified as "OIL" and produced liquids in a given year are "Oil Wells." Assume that any wells classified as "GAS" or "O&G" that produced liquids but zero gas in a given year are also "Oil Wells."
    d. Choose and apply a GOR threshold to classify co-producing "O&G" wells—for example, GOR ≥ 100 mcf/bbl wells are "Non-associated Gas Wells" and GOR <100 mcf/bbl are "Oil Wells." *Note: Table 2 shows counts according to a GOR threshold of 100 mcf/bbl, but other threshold values may be considered.*
    e. Assume that any co-producing "OIL" or "O&G" wells are "Associated Gas Wells."
    f. Estimate emissions from existing emission sources and methodology currently in the natural gas and petroleum systems calculation spreadsheets.
2. For each year, classify all active production wells in the DrillingInfo database as either "Gas Wells" or "Oil Wells" based solely on GOR.
    a. For each well, calculate GOR using actual gas and hydrocarbon liquids data reported by DrillingInfo. Note, this approach does not take into account any production classification information reported by the operator, and includes all hydrocarbon liquids (including condensate) production in the GOR denominator.
    b. Choose and apply a GOR threshold to classify wells as "Gas Wells" or "Oil Wells"—for example, GOR ≥ 100 mcf/bbl wells are gas and GOR <100 mcf/bbl are oil. *Note: Table 2 shows counts according to a GOR threshold of 100 mcf/bbl, but other threshold values may be considered.*

   c. Estimate emissions from existing emission sources and methodology currently in the natural gas and petroleum systems calculation spreadsheets, except that that "Gas Wells" will be treated as "Non-associated Gas Wells" currently are, and "Associated Gas Wells" will no longer be a component of the natural gas systems estimate.

3. For each year, classify all active production wells in the DrillingInfo database as either "Gas Wells" or "Oil Wells," then define an oil well sub-population as "Associated Gas Wells," all based solely on GOR.
   a. Follow Option 2 steps 'a' and 'b' above.
   b. Choose and apply a GOR threshold to identify a sub-population of "Oil Wells" that produce substantial amounts of gas and should be classified as "Associated Gas." *Note: Table 2 shows counts according to a GOR threshold of 12.5 mcf/bbl, but other threshold values may be considered.*
   c. Estimate emissions from existing emission sources and methodology currently in the natural gas and petroleum systems calculation spreadsheets.

Table 2. Previous Inventory Well Counts Compared to 2015 Well Counts Options

Well Population	Methodology	2000	2005	2010	2011	2012
2012 Natural Gas Inventory						
Associated Gas Wells	1990 to 2004 data: API *Basic Petroleum Book* – Producing Oil Wells 2005 to 2010 data: World Oil Magazine – Producing Oil Wells	246,700	230,604	245,309	Not reported	Not reported
Non-Associated Gas Wells	1990 to 2003 data: U.S. DOE/EIA – Producing Gas Wells 2004 to 2010 data: World Oil Magazine – Producing Gas Wells	341,678	395,272	484,795	Not reported	Not reported
Hydraulically Fractured	From state oil and gas inventories of CBM and Barnett shale wells (TX only)	6,892	16,949	50,434	Not reported	Not reported
2014 Natural Gas Inventory						
Non-Associated Gas Wells	• 'GAS' wells with > 0 gas production • 'OIL' or 'O&G' wells with no liquids production and > 0 gas production	292,004	379,602	466,884	469,426	470,913
Hydraulically Fractured	Subset of Non-Associated Gas Wells that were horizontally drilled or are in coalbed, shale, or tight gas reservoirs (as classified using the EIA Crosswalk)	112,547	166,966	220,400	226,038	227,862
Associated Gas Wells	'OIL' or 'O&G' wells with > 0 liquids and gas production	295,188	286,514	310,310	316,065	323,392
2014 Petroleum Inventory						
Oil Wells	From EIA	534,000	498,000	520,000	536,000	536,000[a]
Stripper Wells[d]	From IOGCC; subset of Oil Wells	411,629	401,072	394,016	394,016	394,016
2014 Inventory Total Active Wells (Non-Associated Gas Wells + Oil Wells)		**826,004**	**877,602**	**986,884**	**1,005,426**	**1,006,913**
2015 Proposed Option 1 [b]						
Gas Wells	• 'GAS' wells with > 0 gas production • 'OIL' wells with no liquids production and > 0 gas production • 'O&G' wells with GOR ≥ 100 MCF/bbl	286,339	371,092	494,336	485,927	485,916
Hydraulically Fractured[c]	Subset of Gas Wells that were horizontally drilled or are in coalbed, shale, or tight gas reservoirs (as classified using the EIA Crosswalk)	128,546	188,012	266,010	264,304	267,213
Oil Wells	• 'OIL' wells with > 0 liquids production • 'GAS' wells with no gas production and > 0 liquids production • 'O&G' wells with GOR < 100 MCF/bbl	407,868	404,084	763,027	774,052	793,156
Hydraulically Fractured[c]	Subset of Oil Wells that were horizontally drilled or are in coalbed, shale, or tight gas reservoirs (as classified using the EIA Crosswalk)	73,291	79,985	148,979	161,388	175,600
Associated Gas Wells	Oil Wells with > 0 gas production	202,306	209,958	402,636	410,591	425,331
Stripper Wells[d]	Subset of Oil Wells with ≤ 10 bbl/day liquids production (3,650 bbl/year)	133,188	140,208	322,534	322,133	324,692

Table 2. Previous Inventory Well Counts Compared to 2015 Well Counts Options

Well Population	Methodology	2000	2005	2010	2011	2012
2015 Inventory Total Active Wells – Option 1		**694,207**	**775,176**	**1,257,363**	**1,259,979**	**1,279,072**

Table 2. Previous Inventory Well Counts Compared to 2015 Well Counts Options

Well Population	Methodology	2000	2005	2010	2011	2012
2015 Proposed Option 2 [b]						
Gas Wells	Wells with GOR ≥ 100 MCF/bbl	265,699	342,900	456,845	448,371	446,237
Hydraulically Fractured[c]	Subset of Gas Wells that were horizontally drilled or are in coalbed, shale, or tight gas reservoirs (as classified using the EIA Crosswalk)	118,580	173,314	245,348	242,840	243,947
Oil Wells	Wells with GOR < 100 MCF/bbl	428,508	432,276	800,518	811,608	832,835
Hydraulically Fractured[c]	Subset of Oil Wells that were horizontally drilled or are in coalbed, shale, or tight gas reservoirs (as classified using the EIA Crosswalk)	83,257	94,683	169,641	182,852	198,866
Associated Gas Wells	N/A – Remove from Natural Gas Inventory					
Stripper Wells[d]	Subset of Oil Wells with ≤ 10 bbl/day liquids production (3,650 bbl/year)	312,626	316,710	669,887	671,715	677,514
2015 Inventory Total Active Wells – Option 2		**694,207**	**775,176**	**1,257,363**	**1,259,979**	**1,279,072**
2015 Proposed Option 3 [b]						
Gas Wells	Wells with GOR ≥ 100 MCF/bbl	265,699	342,900	456,845	448,371	446,237
Hydraulically Fractured[c]	Subset of Gas Wells that were horizontally drilled or are in coalbed, shale, or tight gas reservoirs (as classified using the EIA Crosswalk)	118,580	173,314	245,348	242,840	243,947
Oil Wells	Wells with GOR < 100 MCF/bbl	428,508	432,276	800,518	811,608	832,835
Hydraulically Fractured[c]	Subset of Oil Wells that were horizontally drilled or are in coalbed, shale, or tight gas reservoirs (as classified using the EIA Crosswalk)	83,257	94,683	169,641	182,852	198,866
Associated Gas Wells	Subset of Oil Wells with GOR ≥ 12.5 MCF/bbl	53,856	62,351	82,617	82,384	85,456
Stripper Wells[d]	Subset of Oil Wells with ≤ 10 bbl/day liquids production (3,650 bbl/year)	312,626	316,710	669,887	671,715	677,514
2015 Inventory Total Active Wells – Option 3		**694,207**	**775,176**	**1,257,363**	**1,259,979**	**1,279,072**

a – EIA has not published 2012 final value. This number is EIA's 2011 estimate carried forward unchanged.

b –The 2015 proposed options do not include state-specific manipulations performed to develop final well populations for natural gas systems. For the 2014 Inventory, the state-specific manipulations included: early time series years for KY (operators were not required to report production prior to 1997), and later time series years for KY, TN, and MD (there is a lag in publically available data for these states). The counts presented in this memorandum are using OECA's May 2014 data release of DrillingInfo. However, the final 2015 Inventory counts will use a future OECA release (scheduled for December 2014). As a result, state-specific manipulations necessary for the 2015 proposed options may not be necessary with the future OECA release. Differences between OECA's May 2014 data release and the future OECA release will include: 2011 data for KY (currently only through 2010); 2012 and 2013 data for MD (currently only through 2011); and 2013 for 24 additional states (currently only partially complete for 2013, which is why 2013 counts are not included in this memorandum). As a result of using the future OECA data release and implementing the state-specific manipulations, the counts for 2011 through 2013 will increase.

c – Though not a topic discussed in this memorandum, the counts of hydraulically fractured gas and oil wells using current Inventory methodology are shown for the proposed 2015 Inventory options.

d – Though not a topic discussed in this memorandum, the counts of stripper wells (a subset of oil wells) for the proposed 2015 Inventory options are calculated based on DrillingInfo production data (whereas current methodology obtains stripper well counts from IOGCC).

Comparison of Approaches Under Consideration

Option 1 retains the current Inventory methodology for identifying "Non-associated Gas Wells" and "Associated Gas Wells." This approach will produce well count activity data most consistent with previous Inventories. Option 1 is the only option that gives weight to the production type classification field in the OECA-processed version of the DrillingInfo database (this field is based on an OECA-developed crosswalk that assigns the hundreds of reported state production types into simplified categories of 'GAS', 'OIL', and 'O&G'); using this production type classification field does not lend itself to straightforward reproduction of well counts by non-EPA entities. Option 1 carries forward the current methodology of addressing a sub-population of oil wells that are "Associated Gas Wells," which is relatively simple: any wells with production type of 'OIL' or 'O&G' that produce any amounts of both oil and gas in a given year are considered "Associated Gas Wells." Option 3 discussed below also develops a population of "Associated Gas Wells" but by a more nuanced approach that takes into account the relative amounts of oil and gas from co-producing wells (e.g., a well that produces only 10 mcf gas and 20,000 bbl oil per year may not be considered "Associated Gas").

Both Options 2 and 3 simplify the current Inventory methodology in the interest of easier reproducibility; wells are apportioned into categories based on solely on GOR, with no consideration to the OECA-assigned production type classification. Option 2 additionally simplifies the current Inventory methodology in that associated gas wells are not a separate sub-population within natural gas systems; however, the disadvantage that comes with this simplification is that emissions from oil wells that produce some gas (but less than the GOR threshold chosen to define gas wells, e.g., 100 mcf/bbl) will be quantified solely by the petroleum systems "Oil Well" emission sources and factors. Option 2 may therefore underestimate emissions from oil wells that produce substantial gas.

Option 3 is a more in-depth approach compared to Option 2 because it treats oil wells with significant gas production differently than "Non-associated Gas Wells" or "Oil Wells" (as they could be expected to have emissions somewhere between the two populations). Two main challenges come into consideration with Option 3:

1. Potentially revised emission sources and methodology will need to be developed for the "Associated Gas Wells" population. The current Inventory methodology is a starting point, but it only assigns one emission source to "Associated Gas Wells" – fugitives from meters/piping. Appendix A below details the activity data basis and general methodology for production sector emission sources in the natural gas and petroleum systems inventories, for further consideration on this topic. EPA is considering whether this one emission source accurately represents the incremental emissions from an "Associated Gas Well" compared to an "Oil Well."
2. The GOR selected to define the "Associated Gas Wells" population will need to be thoughtfully chosen and well-documented. Table 2 presents counts based on 12.5 mcf/bbl, which is a value cited in an attachment to an EPA white paper regarding hydraulically fractured oil well completions. The basis for the 12.5 value is unclear. A value should be selected to acknowledge that it is intended to represent oil wells with significant gas production (i.e., would have more GHG emissions than the typical oil well)—but not represent oil-producing wells that have so much gas production that they should actually be classified as gas wells.

Request for Stakeholder Feedback

EPA seeks stakeholder feedback on the following topics:

- Relying on DrillingInfo to generate all well count populations for the 2015 Inventory.
- The three methodology options presented in this memorandum for using DrillingInfo to generate well count populations:
    - **Option 1**: For each year, classify all active production wells in the DrillingInfo database as "Non-associated Gas Wells," "Oil Wells," and "Associated Gas Wells" (a sub-population of oil wells)—starting with existing Inventory methodology for natural gas systems.
    - **Option 2**: For each year, classify all active production wells in the DrillingInfo database as either "Gas Wells" or "Oil Wells" based solely on GOR.

- **Option 3**: For each year, classify all active production wells in the DrillingInfo database as either "Non-associated Gas Wells" or "Oil Wells," then define an oil well sub-population as "Associated Gas Wells," all based solely on GOR.

- The identification of GOR threshold values that can be used to delineate "Non-associated Gas Wells" from "Oil Wells" (100 mcf/bbl as a reasonable example) and to delineate "Associated Gas Wells" from "Oil Wells" (12.5 mcf/bbl as a reasonable example).
- Whether there are other methodological revisions that would improve accuracy of well count populations and sub-populations. Note, EPA is also considering reassessing the completions and workover population counts to determine whether they should be based on DrillingInfo instead of GHGRP. Please see memorandum *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2013: Proposed Revision to Hydraulically Fractured Gas Well Completions and Workovers Estimate*.
- Methodological revisions to how emissions from "Associated Gas Wells" are currently calculated. The current Inventory methodology assigns one emission source to "Associated Gas Wells" (fugitives from meters/piping) in addition to the emission sources that are accounted for with all oil wells. Are there other emission sources that should be applied to the "Associated Gas Wells" population? Or other methodology revisions to account for emissions from these wells?

Appendix A:
Current Production Sector Methodology

This appendix further documents the current methodology for the production sector, which relies on source-level emissions that are typically calculated by applying emission factors to either: (1) a well counts population value; or (2) a throughput value. For example, emissions from small reciprocating compressors are calculated by applying an emission factor to the annual number of non-associated gas wells; and emissions from condensate tank vents are calculated by applying an emission factor to the annual condensate production volume obtained from EIA.

This appendix is intended to facilitate contemplating how emission sources will be applied to different well populations once DrillingInfo data are used to develop all well populations—in particular, if a sub-population of "Associated Gas Wells" is included in the chosen 2015 approach. As shown in Table 1 of this document, the current methodology only accounts for fugitive emissions from field separation equipment as the incremental emissions generated by "Associated Gas" compared to "Oil" wells. Implementing the Option 1 or Option 3 approaches presented in this document may involve reconsideration as to whether there are additional emission sources currently calculated in the natural gas systems production sector of the Inventory that make sense to apply to "Associated Gas Wells."

Table A1. Inventory Natural Gas and Petroleum Systems Onshore Production Emission Source and Activity Factor Bases

Emission Source	Activity Factor Basis		Calculation Comments
	General Basis	Description	
Natural Gas Systems – **FUGITIVE**			
Gas Wells			
Associated Gas Wells	N/A	Emissions are currently accounted for in the Petroleum Systems Inventory	
Non-Associated Gas Wells	Population Based – Well Count	Annual number of non-associated gas wells without hydraulic fracturing	
Gas Wells with Hydraulic Fracturing	Population Based – Well Count	Annual number of gas wells with hydraulic fracturing	
Field Separation Equipment			
Heaters Separators Dehydrators	Population Based – Well Count	Annual total number of non-associated gas wells (with and without hydraulic fracturing)	
Meters/Piping	Population Based – Well Count	Annual total number of associated and non-associated gas wells (with and without hydraulic fracturing)	
Gathering Compressors			
Small Reciprocating Compressors	Population Based – Well Count	Annual total number of non-associated gas wells (with and without hydraulic fracturing)	
Large Reciprocating Compressors Large Reciprocating Stations	Population Based – Pipeline Miles	Annual total gathering pipeline miles	
Pipeline Leaks	Population Based – Pipeline Miles	Annual total gathering pipeline miles	
	Population Based – Well Count	Annual total number of non-associated gas wells (with and without hydraulic fracturing)	
Natural Gas Systems – **VENTED AND COMBUSTED**			
Drilling, Well Completion, and Well Workover			
Gas Well Completions without Hydraulic Fracturing	Population Based – Well Count	Annual percent of non-associated gas well count (with and without hydraulic fracturing) per NEMS Region and total	Ratio the annual value to 1992, which is the basis for the emissions.
Gas Well Workovers without Hydraulic Fracturing	Population Based – Well Count	Annual number of non-associated gas wells without hydraulic fracturing	
Hydraulic Fracturing Completions and Workovers	Population Based – Event Count	Events counted in each control technology category based on GHGRP data. See Annex for documentation of extrapolation to cover time series beginning in 1990.	From GHGRP

Table A1. Inventory Natural Gas and Petroleum Systems Onshore Production Emission Source and Activity Factor Bases

Emission Source	Activity Factor Basis		Calculation Comments
	General Basis	Description	
Well Drilling	Population Based – Well Count	Annual number of gas wells drilled	From EIA
	Population Based – Well Count	Annual percent of non-associated gas well count (with and without hydraulic fracturing) per NEMS Region	
Produced Water from Coal Bed Methane			
Powder River	Production Based	Annual gallons of water produced for Powder River Basin CBM wells	From Wyoming Oil and Gas Conservation Commission
Black Warrior	Population Based – Well Count	Annual number of producing CBM wells in Black Warrior Basin	From Geological Survey of Alabama – State Oil and Gas Board
Normal Operations			
Pneumatic Device Vents Chemical Injection Pumps Kimray Pumps Dehydrator Vents	Population Based – Well Count	Annual total number of non-associated gas wells (with and without hydraulic fracturing)	
Condensate Tank Vents			
Condensate Tanks without Control Devices Condensate Tanks with Control Devices	Production Based	Annual condensate production	From EIA
Compressor Exhaust Vented			
Gas Engines	Population Based – Well Count	Annual percent of total non-associated gas well count (with and without hydraulic fracturing), excluding NE NEMS Region	Ratio the annual value to 1992, which is the basis for the emissions Gas wells in NE NEMS Region are not driven by low pressure gas from the well; only applies to the other NEMS Regions
Well Clean Ups			
Well Clean Ups (LP Gas Wells) – Vent Using Plungers Well Clean Ups (LP Gas Wells) – Vent without Using Plungers	Population Based – Well Count	Annual total number of non-associated gas wells (with and without hydraulic fracturing)	
Blowdowns			
Vessel Blowdowns Compressor Blowdowns Compressor Starts	Population Based – Well Count	Annual total number of non-associated gas wells (with and without hydraulic fracturing)	

Table A1. Inventory Natural Gas and Petroleum Systems Onshore Production Emission Source and Activity Factor Bases

Emission Source	Activity Factor Basis		Calculation Comments
	General Basis	Description	
Pipeline Blowdowns	Population Based – Pipeline Miles	Annual total gathering pipeline miles	
	Population Based – Well Count	Annual total number of non-associated gas wells (with and without hydraulic fracturing)	
Upsets			
Pressure Relief Valves	Population Based – Well Count	Annual percent of non-associated gas well count (with and without hydraulic fracturing) per NEMS Region and total	Ratio the annual value to 1992, which is the basis for the emissions
Mishaps	Population Based – Pipeline Miles	Annual total gathering pipeline miles	
	Population Based – Well Count	Annual total number of non-associated gas wells (with and without hydraulic fracturing)	
Petroleum Systems – **VENTED**			
Oil Tanks	Production Based	Annual oil production in the Lower 48	From EIA
	Production Based	Average stripper well oil production	From Interstate Oil and Gas Compact Commission
	Population Based – Well Count	Annual total number of stripper wells	From Interstate Oil and Gas Compact Commission
Pneumatic Devices, High Bleed Pneumatic Devices, Low Bleed Vessel Blowdowns Compressor Blowdowns Compressor Starts	Population Based – Well Count	Annual total number of producing oil wells	From EIA Ratio the annual number of wells and domestic production to the 1993 values, which is the basis for the emissions.
	Production Based	Annual domestic production	From EIA
Chemical Injection Pumps	Production Based	Annual domestic production	From EIA Ratio the annual number of wells and domestic production to the 1993 values, which is the basis for the emissions.
Stripper Wells	Population Based – Well Count	Annual total number of stripper wells	From Interstate Oil and Gas Compact Commission
Well Completion Venting	Production Based – Well Count	Annual total number of crude oil wells drilled	From EIA

Table A1. Inventory Natural Gas and Petroleum Systems Onshore Production Emission Source and Activity Factor Bases

Emission Source	Activity Factor Basis		Calculation Comments
	General Basis	Description	
Well Workovers	Production Based – Well Count	Annual total number of producing oil wells	From EIA
Petroleum Systems – **FUGITIVE**			
Oil Wellheads (Heavy Crude) Oil Wellheads (Light Crude)	Population Based – Well Count	Annual total number of producing oil wells	From EIA
	Population Based – Well Count	Annual total number of stripper wells	From Interstate Oil and Gas Compact Commission
Separators (Heavy Crude) Separators (Light Crude) Heater/Treaters (Light Crude) Compressors	Population Based – Well Count	Annual total number of producing oil wells	From EIA Ratio the annual number of wells and domestic production to the 1993 values, which is the basis for the emissions.
	Production Based	Annual domestic production	From EIA
Headers (Heavy Crude) Headers (Light Crude)	Population Based – Well Count	Annual total number of producing oil wells	From EIA
Floating Roof Tanks			From Industry Panel and Entropy Tank Survey Use the 1995 value for all years
Large Compressors			Use the 1995 value for all years
Sales Areas	Production Based	Annual domestic production	From EIA
Pipelines	Population Based – Pipeline Miles	Total miles of gathering lines	From EIA No EF for this source
Well Drilling	Population Based – Well Count	Annual number of oil wells drilled	From EIA No EF for this source
Battery Pumps	Population Based – Well Count	Annual total number of producing oil wells	From EIA
Petroleum Systems – **COMBUSTED**			
Gas Engines	Population Based – Well Count	Annual total number of producing oil wells	From EIA Ratio the annual number of wells and domestic production to the 1993 values, which is the basis for the emissions.
	Production Based	Annual domestic production	From EIA
Heaters	Production Based	Annual domestic production	From EIA
Well Drilling	Population Based – Well Count	Annual number of oil wells drilled	From EIA

Table A1. Inventory Natural Gas and Petroleum Systems Onshore Production Emission Source and Activity Factor Bases

Emission Source	Activity Factor Basis		Calculation Comments
	General Basis	Description	
Flares	Production Based	Annual oil production in the Lower 48	From EIA
	Production Based	Average stripper well oil production	From Interstate Oil and Gas Compact Commission
	Population Based – Well Count	Annual total number of stripper wells	From Interstate Oil and Gas Compact Commission
Petroleum Systems – **PROCESS UPSETS**			
Pressure Relief Valves	Production Based	Annual domestic production	From EIA
Well Blowouts Onshore	Population Based – Well Count	Annual number of oil wells drilled	From EIA